MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2015/2016

EPM2036 – CONTROL THEORY

(TE / RE / BE)

30 MAY 2016
2.30 p.m. - 4.30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 5 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given .
3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Describe, with the help of a block diagram, the control mechanism of a driver driving a car. Explain each of the elements derived in the block diagram.

[7 marks]

(b) Consider the following transfer function:

$$F(s) = \frac{10}{s^3 + 6s^2 + 11s + 6}$$

(i) Perform the inverse Laplace Transform on $F(s)$ to obtain the time domain transfer function $f(t)$.

[6 marks]

(ii) Calculate $f(t)$ at $t = 0.5$ and $t = 1$.

[2 marks]

(c) Consider the following block diagram:

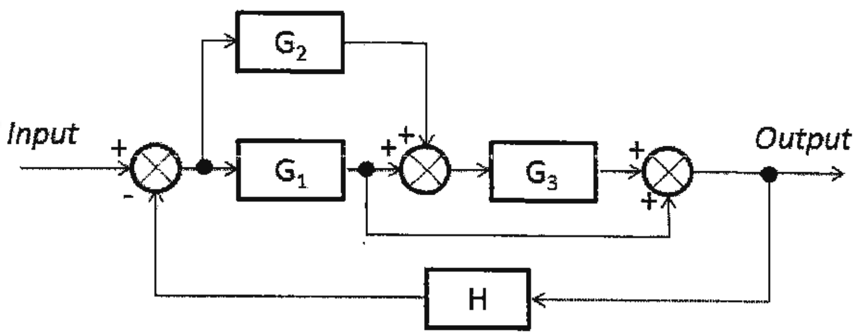

Figure Q1.1 A Typical System's Block Diagram

Reduce the system's block diagram into a single transfer function.

[10 marks]

Continued...

Question 2

(a) Consider the following Signal-Flow-Graph (SFG):

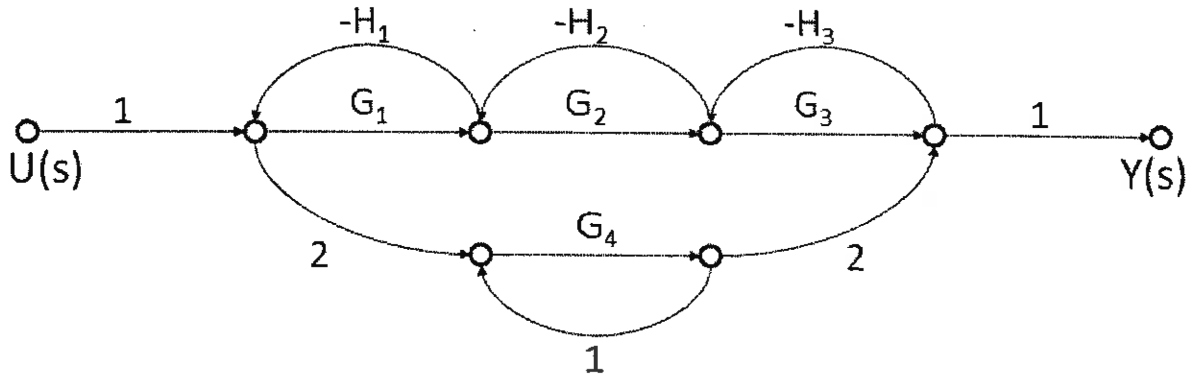

Figure Q2.1 The Signal-Flow-Graph of a Control System

Obtain the transfer function $\dfrac{Y(s)}{U(s)}$ using Mason's Rule. Write down all necessary steps in deriving the transfer function.

[15 marks]

(b) Compare the performance between an ***Underdamped System*** and an ***Overdamped System*** from the following criteria:

(i) Rise Time
(ii) Overshoot
(iii) Steady-State Error

[6 marks]

(c) Consider the following characteristic equation:

$$s^4 + 5s^3 + (k+8)s^2 + 8s + 12k = 0$$

Determine the system's stability with respect to the value of k.

[4 marks]

Continued...

Question 3

(a) Consider the transfer function $KG(s) = \dfrac{K}{s(s+5)(s+20)}$:

(i) Draw the ***Bode Plot*** on the semilog graph if $K = 100$.

[8 marks]

(ii) If K decreases to 50, is the ***Gain Margin*** of the system increased or decreased? Explain.

[2 marks]

(b) Consider a negative unity feedback control system with the following forward path transfer function

$$G(s) = \frac{50}{s(s^2 + 8s + 15)}$$

(i) Sketch the complete Nyquist plot of $G(s)$. Determine the intercepts with the negative real axis, if any.

[12 marks]

(ii) Determine the stability of the system based on the Nyquist Stability criterion.

[3 marks]

Continued...

Question 4

Consider a unity feedback system with the following open-loop transfer function,

$$KG(s)H(s) = \frac{K(s+8)(s+10)}{(s+1)(s+3)}$$

where the system gain $K > 0$.

(a) Applying the root locus method, sketch the trajectories of the closed-loop roots as K is varied from zero to infinity. In the root locus plot, indicate clearly the following:
(i) Starting and ending points of all branches,
(ii) Number of branches,
(iii) Angles and centroids of asymptotes, if any, and
(iv) Root loci on the real axis.

You are NOT required to evaluate the breakaway/break-in points or imaginary axis intercepts, if any.

[9 marks]

(b) Based on the root locus plot obtained in part (a), justify graphically if the response of the above system could achieve settling time of 1 second with an appropriate choice of gain K. Assume that settling time is approximated as $T_s = \dfrac{4}{\xi\omega_n}$.

[2 mark]

(c) Let $K = 1$, design a suitable compensator which is to be placed in series with the above system so that the closed-loop system would achieve
(i) settling time of 1 second, and
(ii) damping ratio of $\xi = 1/\sqrt{2}$.

The transfer function of the compensator is $G_c(s) = \dfrac{K_c(s+z)}{(s+p)}$, where K_c is the compensator gain, and z and p are the suitable zero and pole, respectively. Place the compensator zero at $s = -4$, and determine the remaining design parameters.

Hint: The design points are found at $s_{1,2} = -\xi\omega_n \pm j\omega_n\sqrt{1-\xi^2}$.

[14 marks]

Continued...

Appendix

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $u_s(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{s^n}$
$t^n \ (n = 1, 2, 3, \ldots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!}e^{-at} \quad (n = 1, 2, 3, \ldots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at} \ (n = 1, 2, 3, \ldots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2-\omega^2}$
$\cosh \omega t$	$\frac{s}{s^2-\omega^2}$
$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at}-e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt}-ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$
$\frac{1}{a^2}(1-e^{-at}-ate^{-at})$	$\frac{1}{s(s+a)^2}$

End of paper